B Physics at Tevatron Run II

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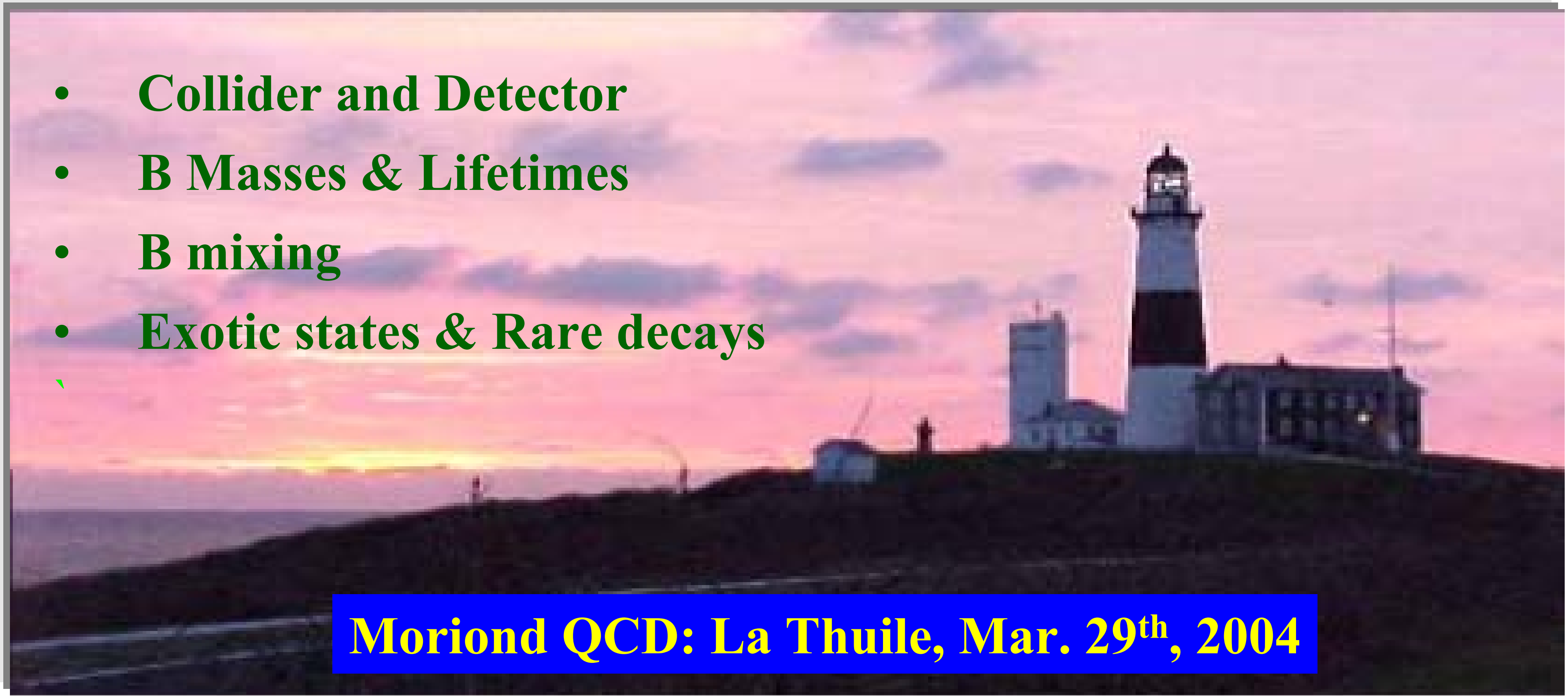
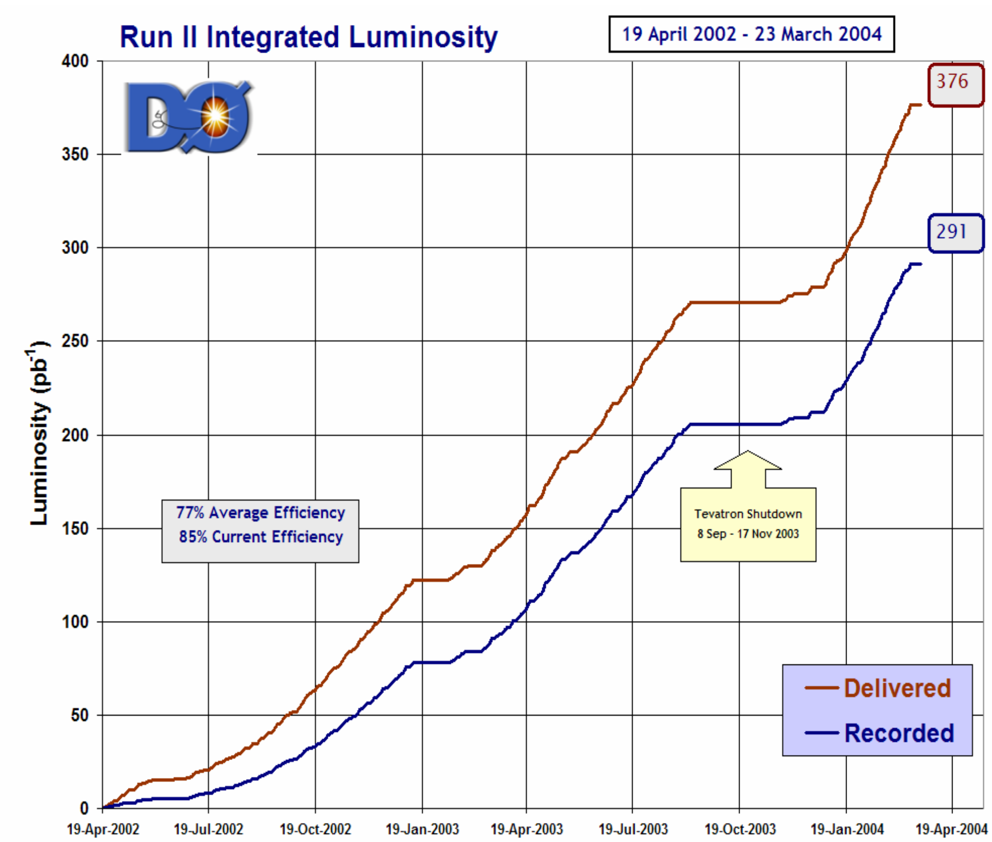


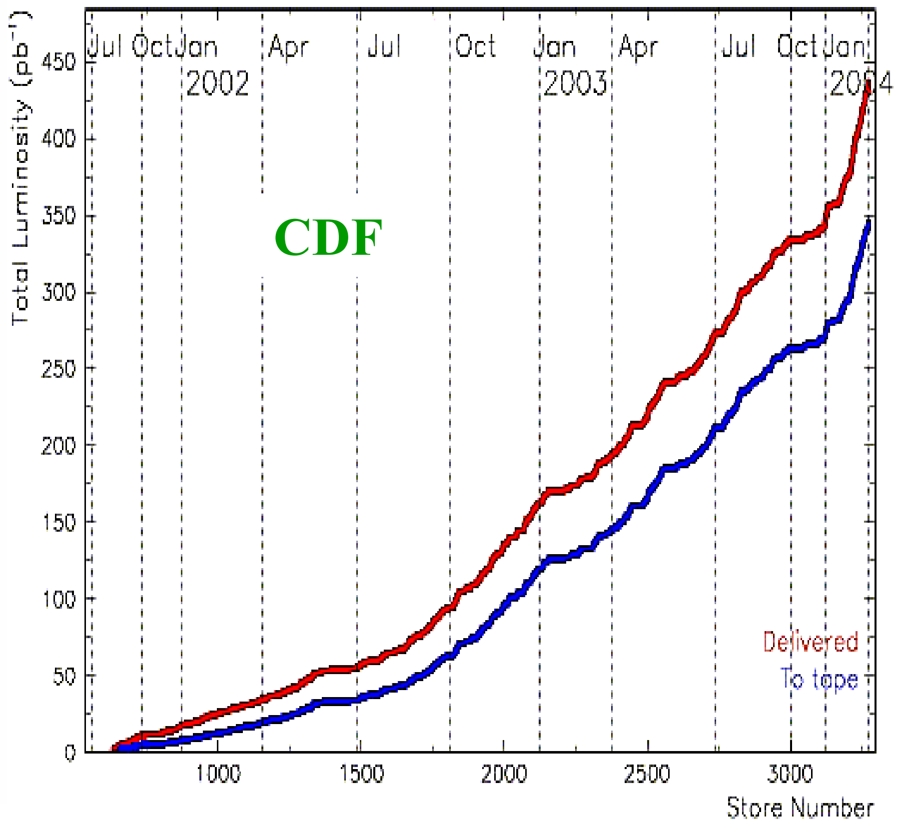
- **Collider and Detector**
- **B Masses & Lifetimes**
- **B mixing**
- **Exotic states & Rare decays**

Moriond QCD: La Thuile, Mar. 29th, 2004

Integrated Luminosities

290 pb^{-1} on tape per experiments

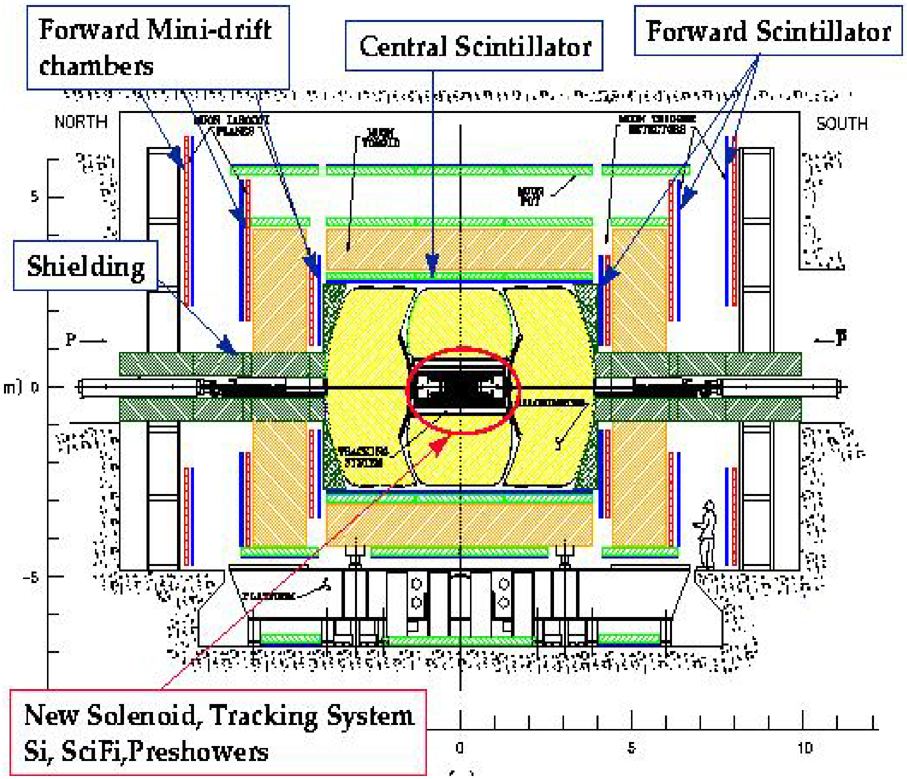




- Data taking efficiency: typically 80-90%
- stable for both experiments

Results in this talk:
CDF analyses: ~65 - 220 pb^{-1}
D∅ analyses : ~115 - 250 pb^{-1}

Detectors



Both detectors

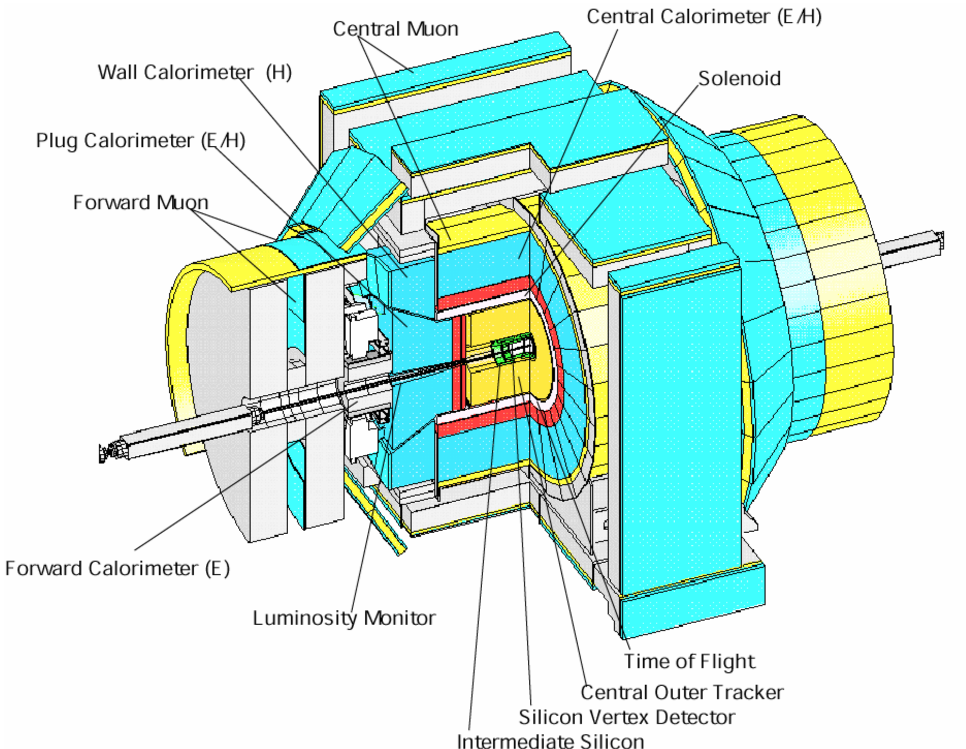
Silicon microvertex tracker
Axial solenoid
Central tracking
High rate trigger/DAQ
Calorimeters and muons

CDF

L2 trigger on displaced vertexes
Particle ID (TOF and dE/dx)
Excellent mass resolution

DØ

Excellent muon ID
Excellent tracking acceptance $|\eta| < 2\text{-}3$
L3 trigger on impact parameter/L2 impact parameter trigger being commissioned



Hadron colliders challenge

- Large production cross section including B_s & Λ_b
- Even larger inelastic cross section

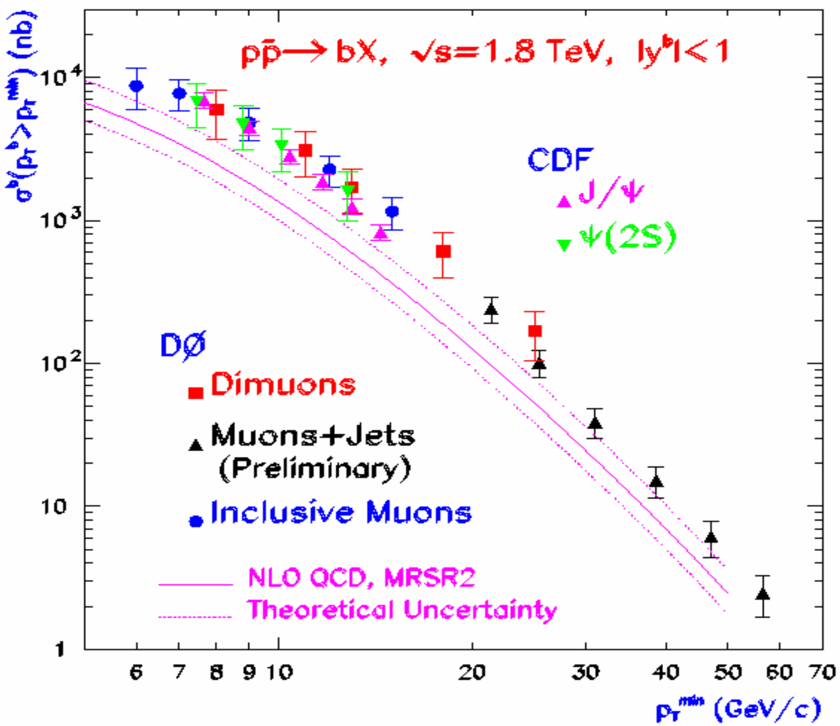
($S/B \approx 10^{-3}$) $\Rightarrow$ specialized triggers:

  - Single lepton triggers
  - Dilepton triggers such as $J/\psi \to \mu^+\mu^-$
  - Track triggers moved to L1 (RunII)
  - In Run II, L2 trigger on displaced tracks using SVX allows CDF to trigger purely hadronic B decays and study such as $B^0 \to \pi^+\pi^-$, $B_s \to D_s^-\pi^+ \ldots$
- Precise 2nd vertex reconstruction

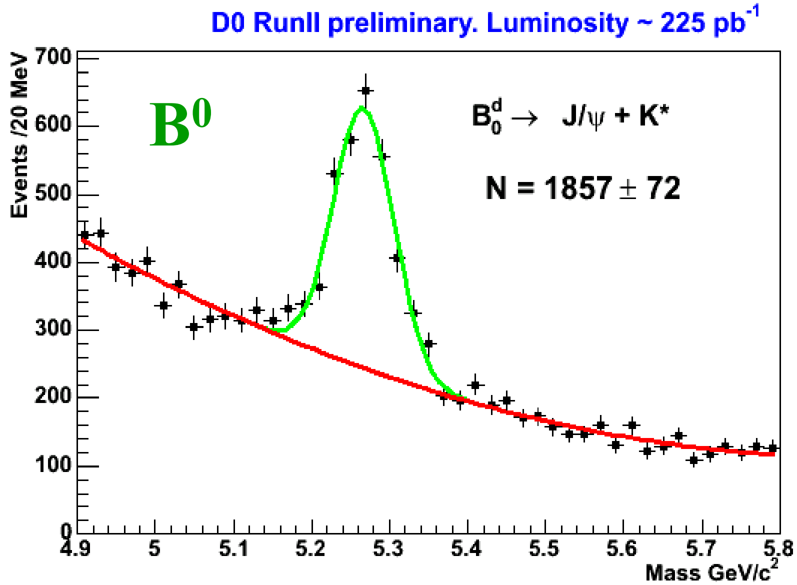
$\sigma(p\bar{p} \to b\bar{b}) \approx 150\,\mu b$ at 2 TeV

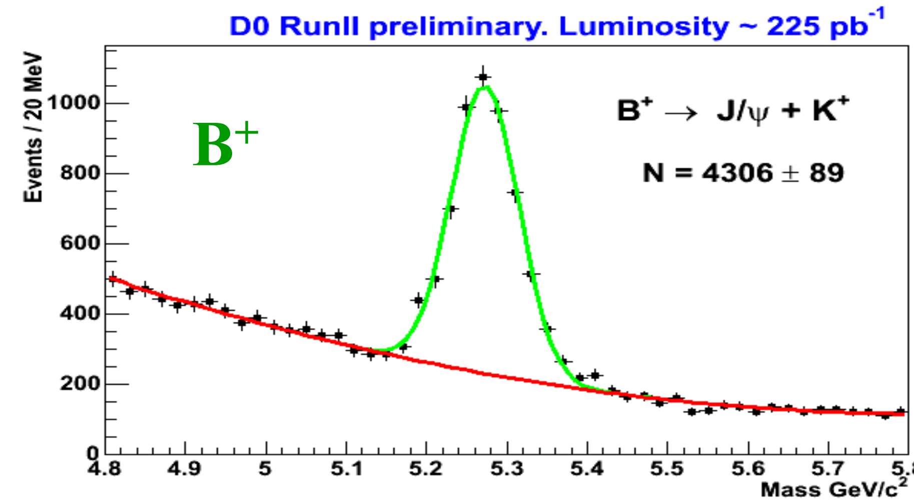
$\sigma(e^+e^- \to b\bar{b}) \approx 7nb$ at Z^0

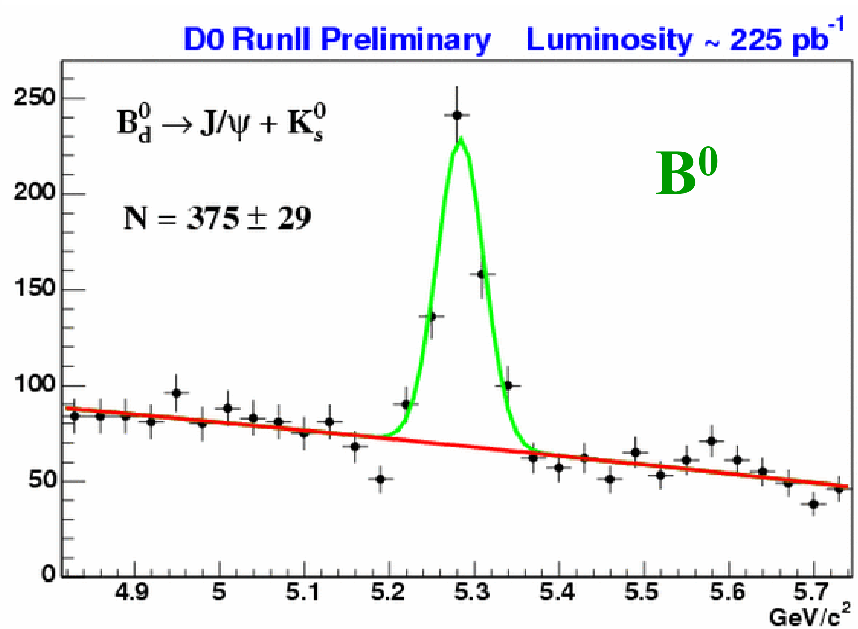
$\sigma(e^+e^- \to B\bar{B}) \approx 1nb$ at $\Upsilon(4S)$



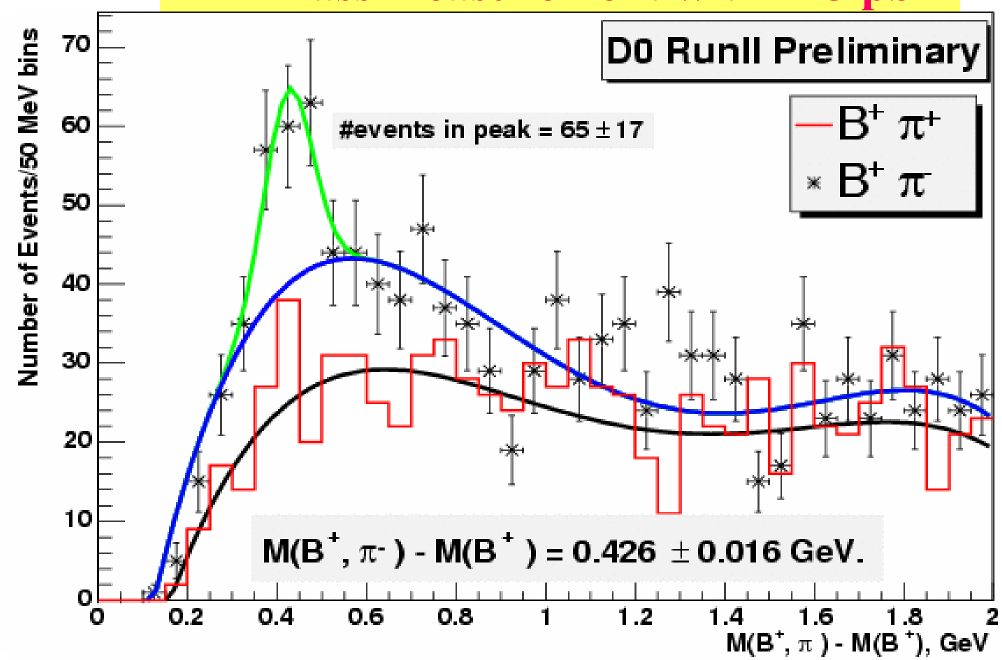
B Hadron yields for DØ





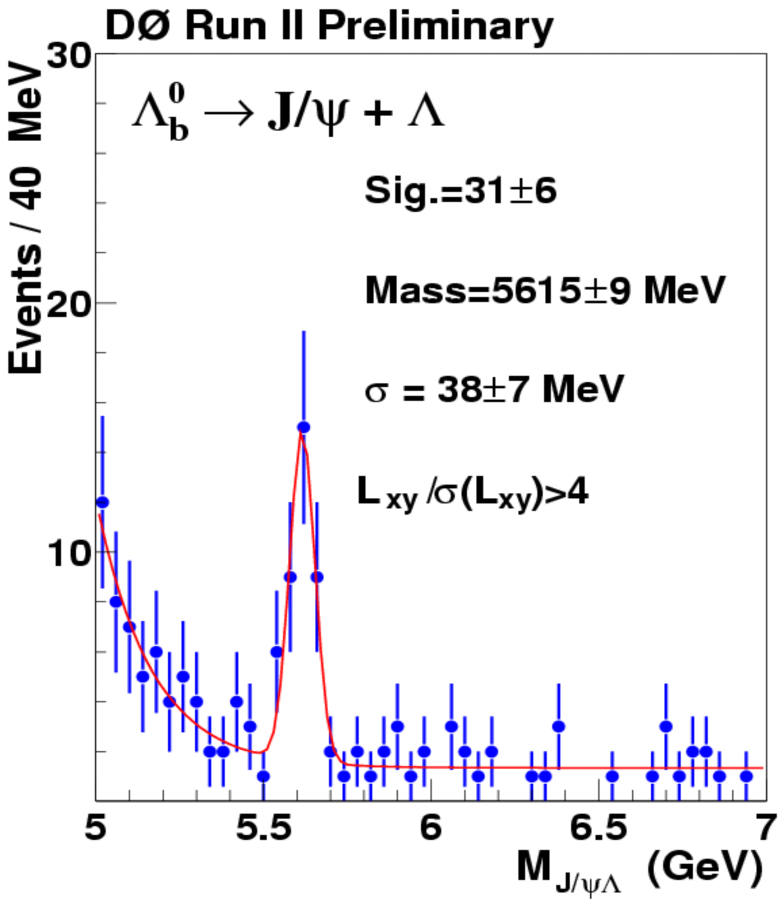


B** mass measurement with 115 pb^{-1}

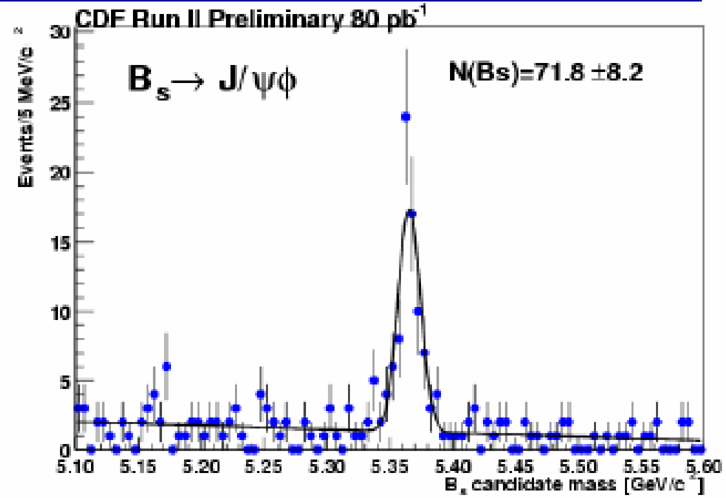


Λ_b and B_S masses

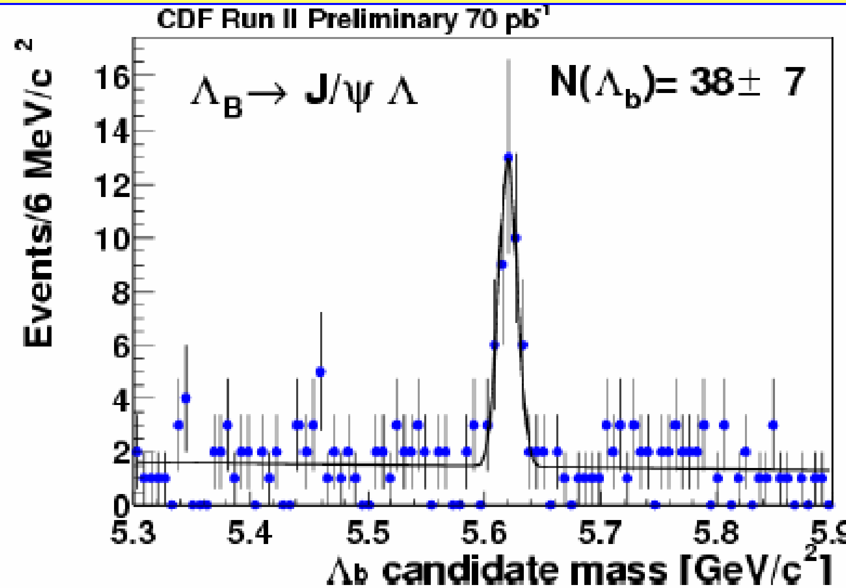
200 pb^{-1}



To be reprocessed with extended tracking ⇒ improve yield by 50%

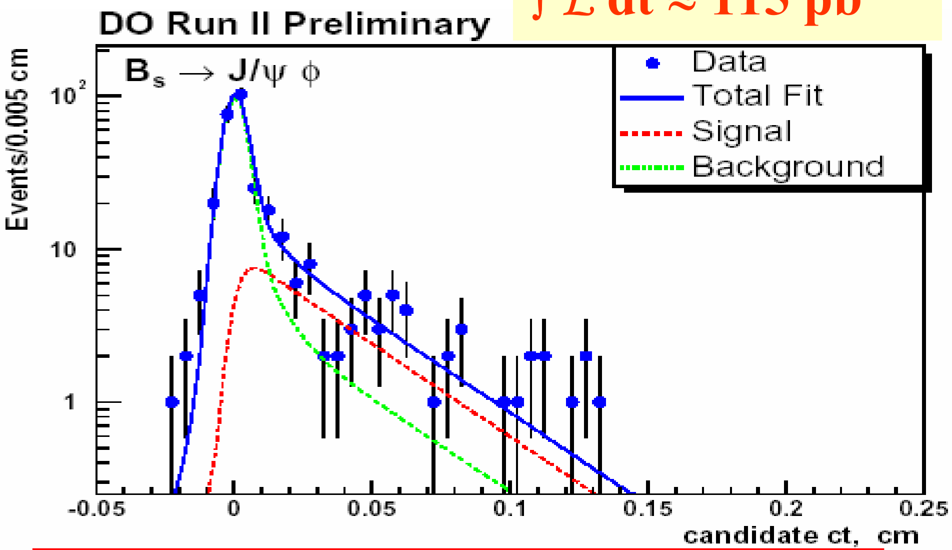


$M(Bs) = 5365.50 \pm 1.29$ (stat) ± 0.94 (sys) MeV/c^2
$M(\Lambda_B) = 5620.4 \pm 1.6$ (stat) ± 1.2 (sys) MeV/c^2
World's best measurements from CDF



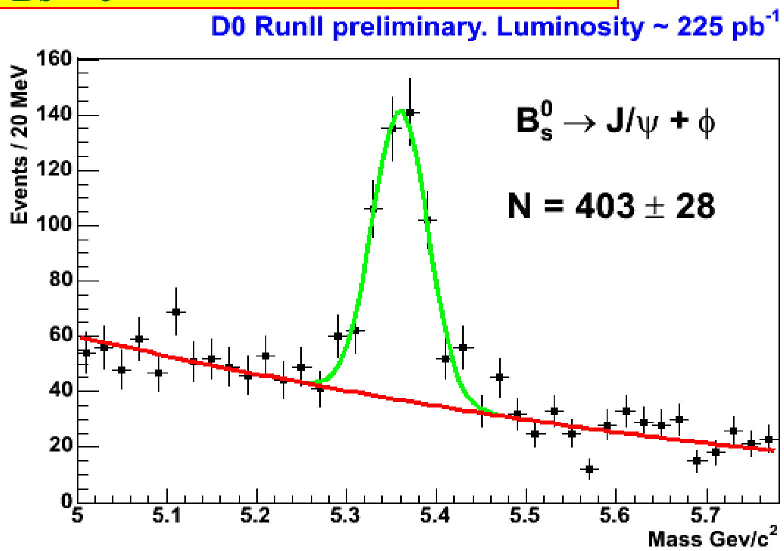
B_s Lifetime

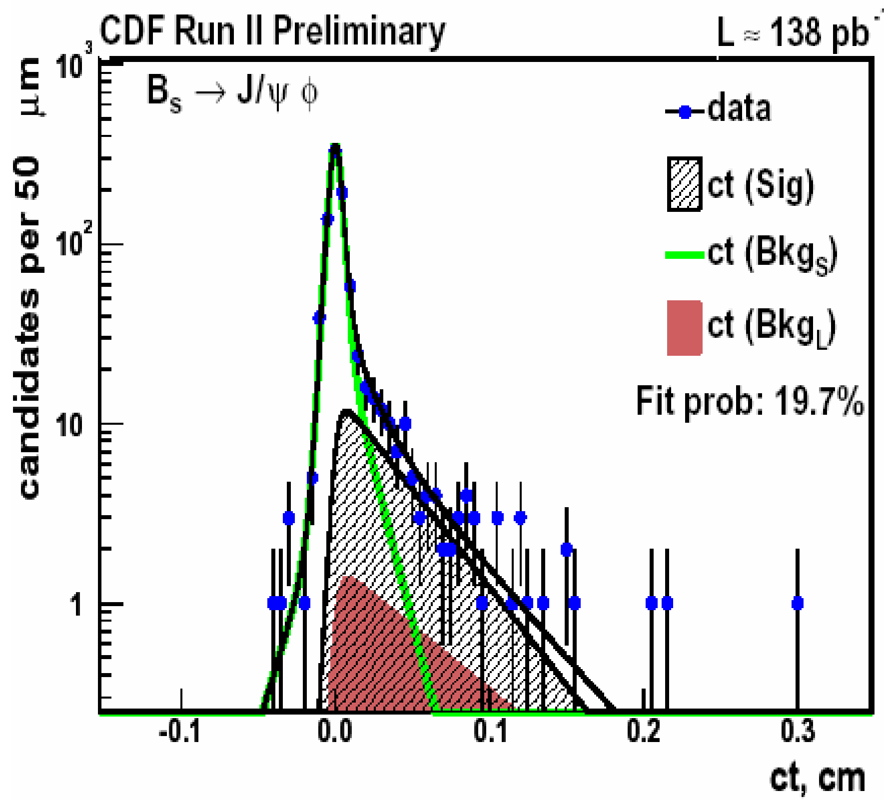
$\int \mathcal{L}\, dt \approx 115\ pb^{-1}$



$$\tau_{Bs} = 1.190\ {}^{+\ 0.19}_{-\ 0.16}\ \text{(stat)}\ \pm 0.14\ \text{(sys)}\ \text{ps}$$

$$\tau_{Bs}/\tau_0 = 0.79 \pm 0.14$$

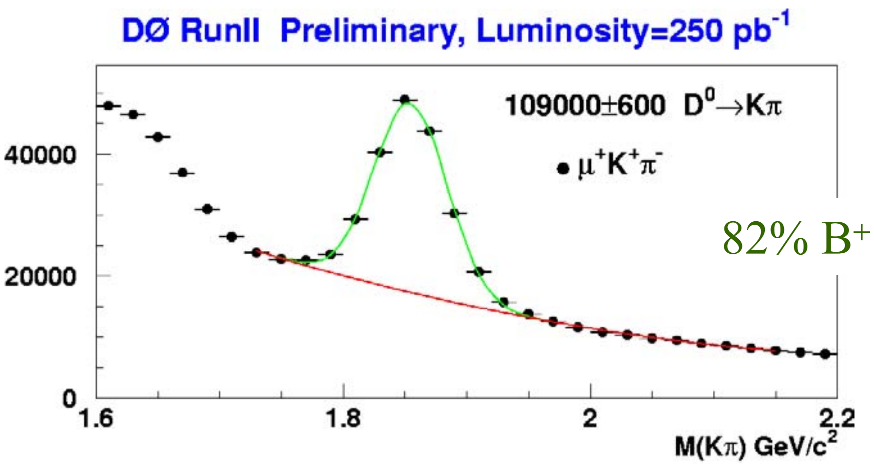


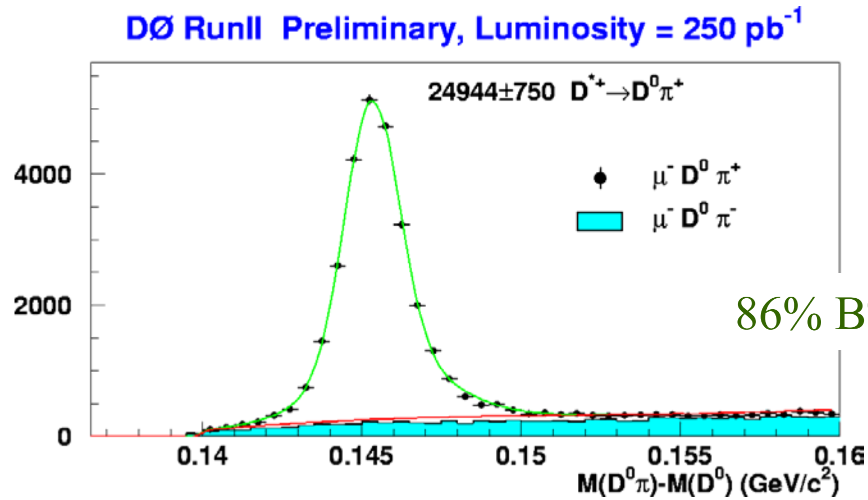


$$\tau_{Bs} = 1.330^{+\ 0.148}_{-\ 0.129}\ \text{(stat)} \pm 0.02\ \text{(sys)}\ \text{ps}$$

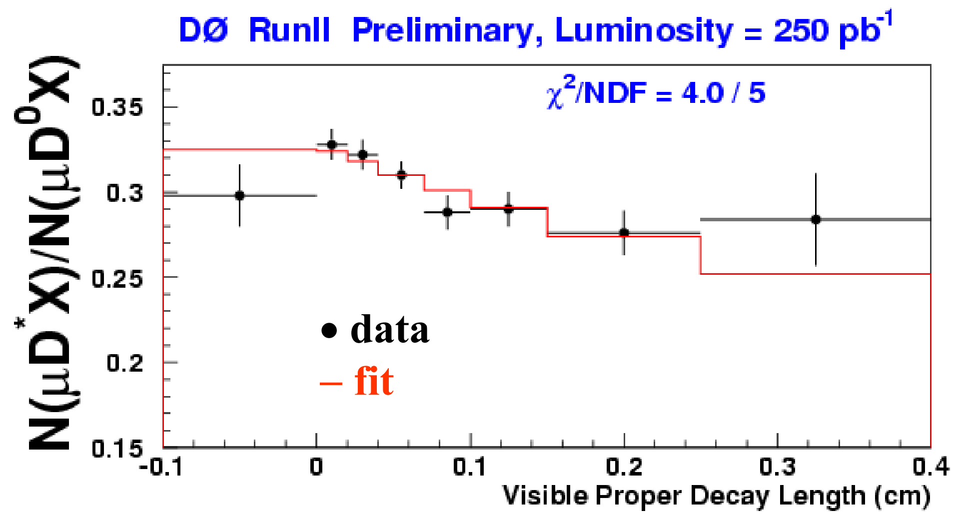
$$\tau_{Bs}/\tau_0 = 0.89 \pm 0.10$$

$\tau(B^+)/\tau(B^0)$ from semileptonic decays





From $B \to \mu^+\nu D^* X$ and $B \to \mu^+\nu D^0 X$ and sample compositions based on measured branching fraction & isospin relations, one can measure the ratio $\tau(B^+)/\tau(B^0)$.



Additional inputs include :

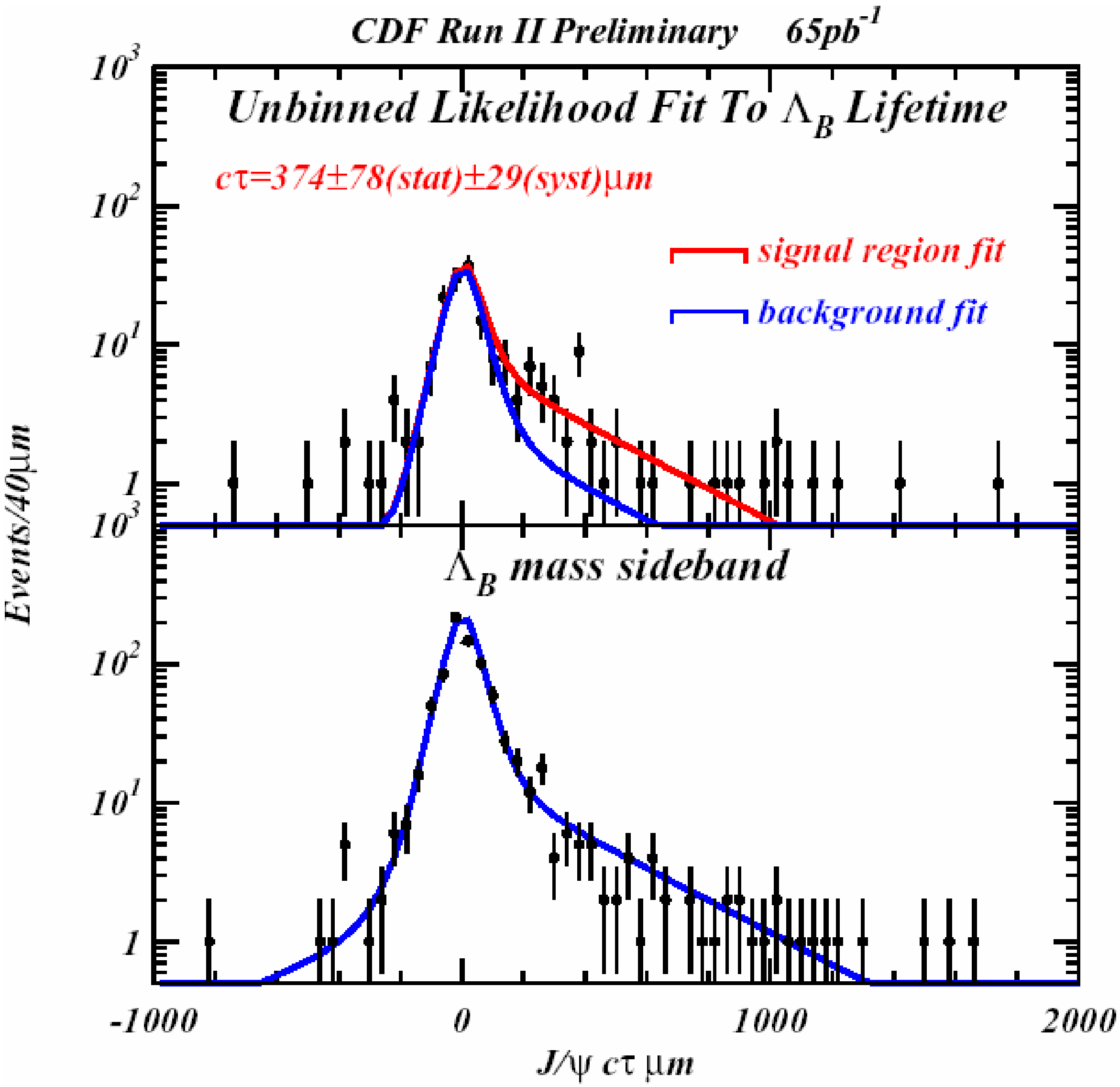
- K-factors (from simulation)
- Relative reconstruction efficiencies for different B decay modes (from simulation)
- Decay length resolution (from simulation)
- fixing $\tau(B^+) = 1.674 \pm 0.018$ ps [PDG]

Preliminary result:

$\tau(B^+)/\tau(B^0) = 1.093 \pm 0.021$ (stat) ± 0.022 (syst)

- one of the most precise measurements

Λ_b Lifetime

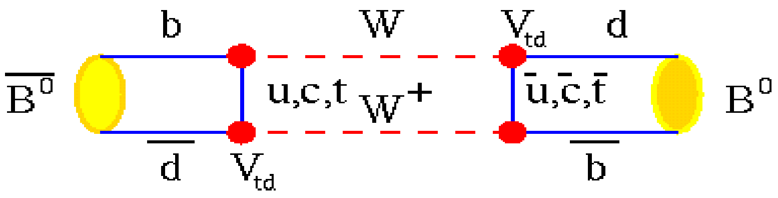


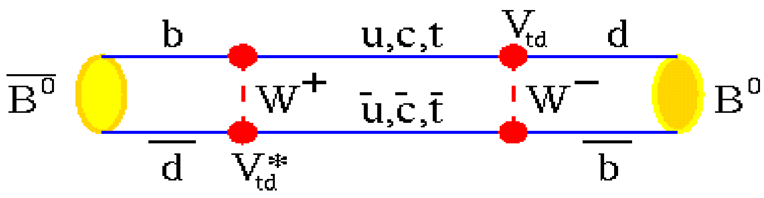
Largest systematic error is from an asymmetric track reconstruction in the COT ~ 26 μm

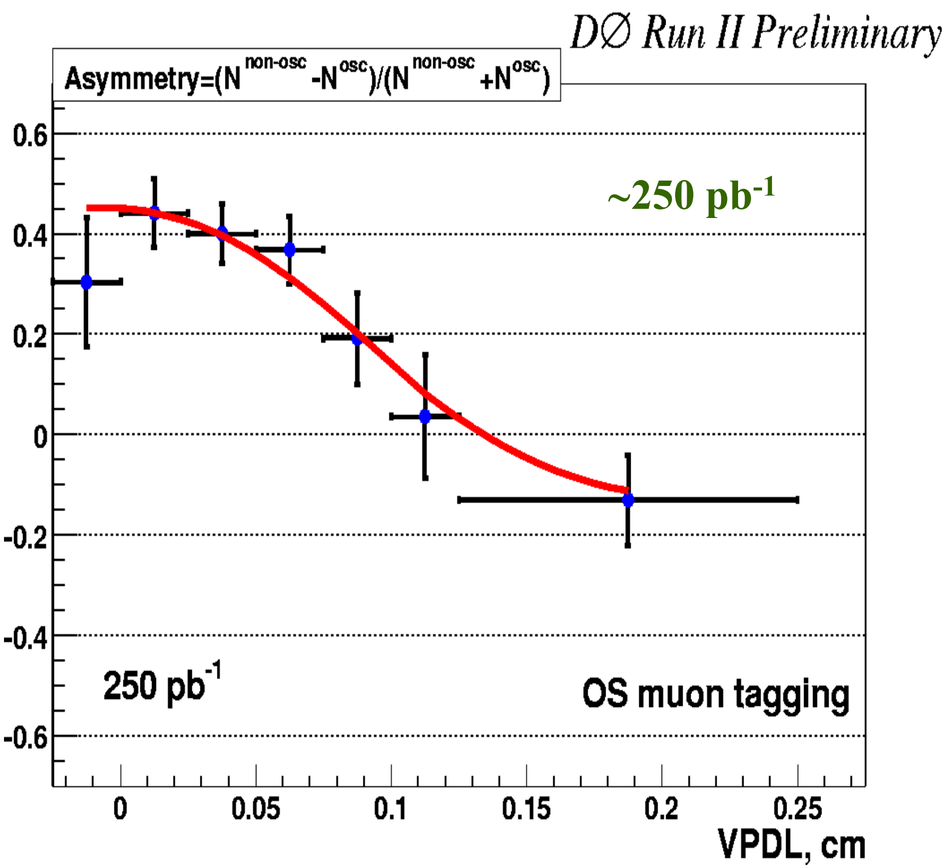
Work is in progress to add more data and use better track reconstruction

$\tau(\Lambda_b)$ measurement in D∅ is in progress

$B^0/\overline{B^0}$ mixing: results from DØ







We use our large sample of semileptonic B0/B0 decays to measure Δm_d:

- This analysis uses opposite-side muon tag
- **Preliminary results:**

$\Delta m_d = 0.506 \pm 0.055$ (stat) ± 0.049 (syst) ps^{-1}

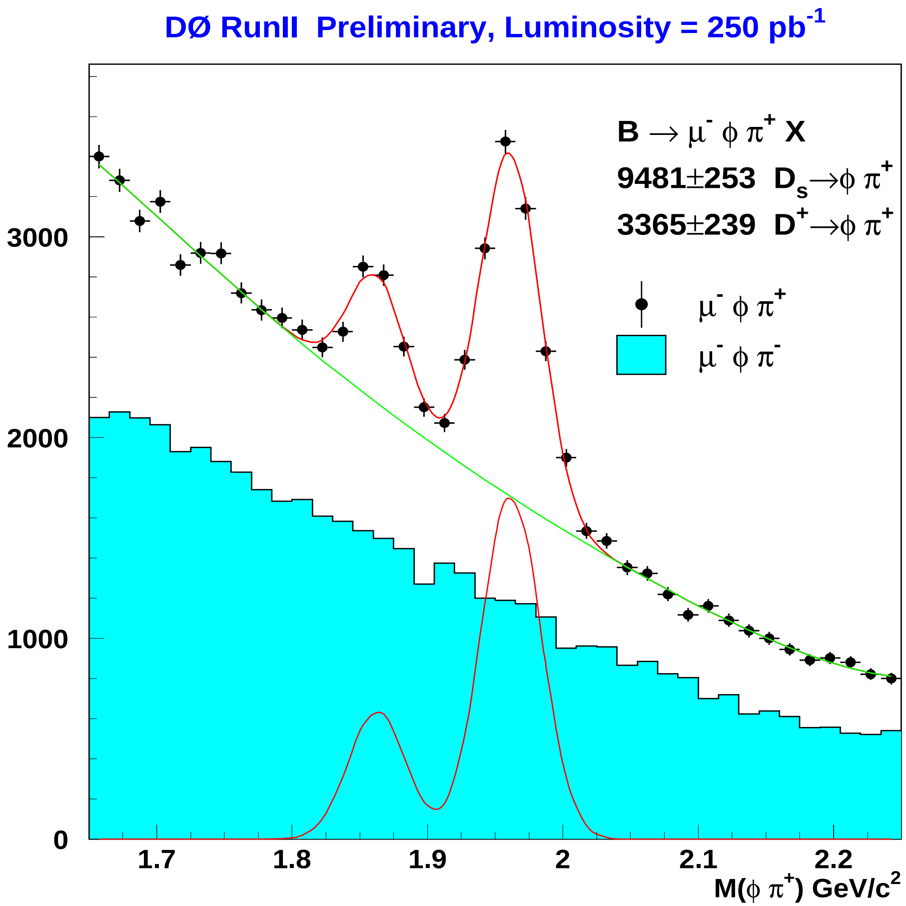
- **Consistent with world average:**

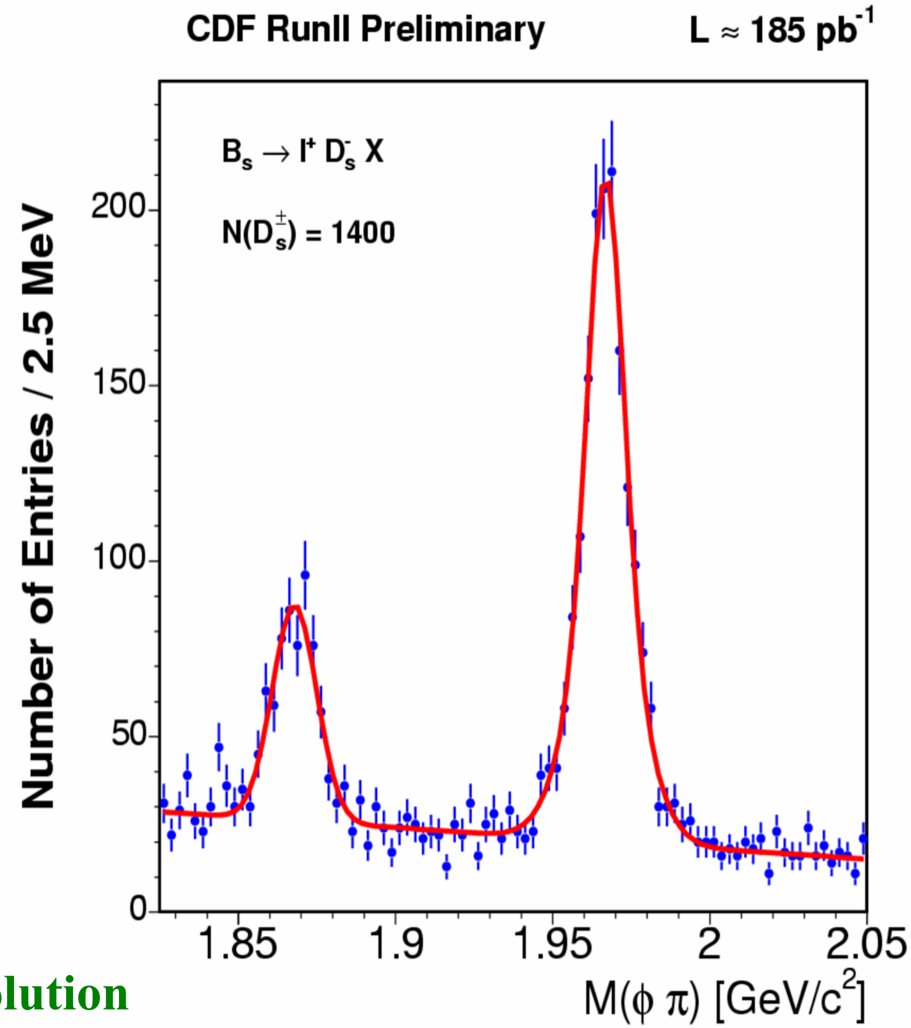
  $0.502 \pm 0.007\ ps^{-1}$
- Tagging efficiency: 4.8 ± 0.2 %
- Tagging purity: 73.0 ± 2.1 %

Work in progress:

- other tagging methods:
  - jet charge,
  - same side tagging
- add more decay channels

Towards B_s mixing

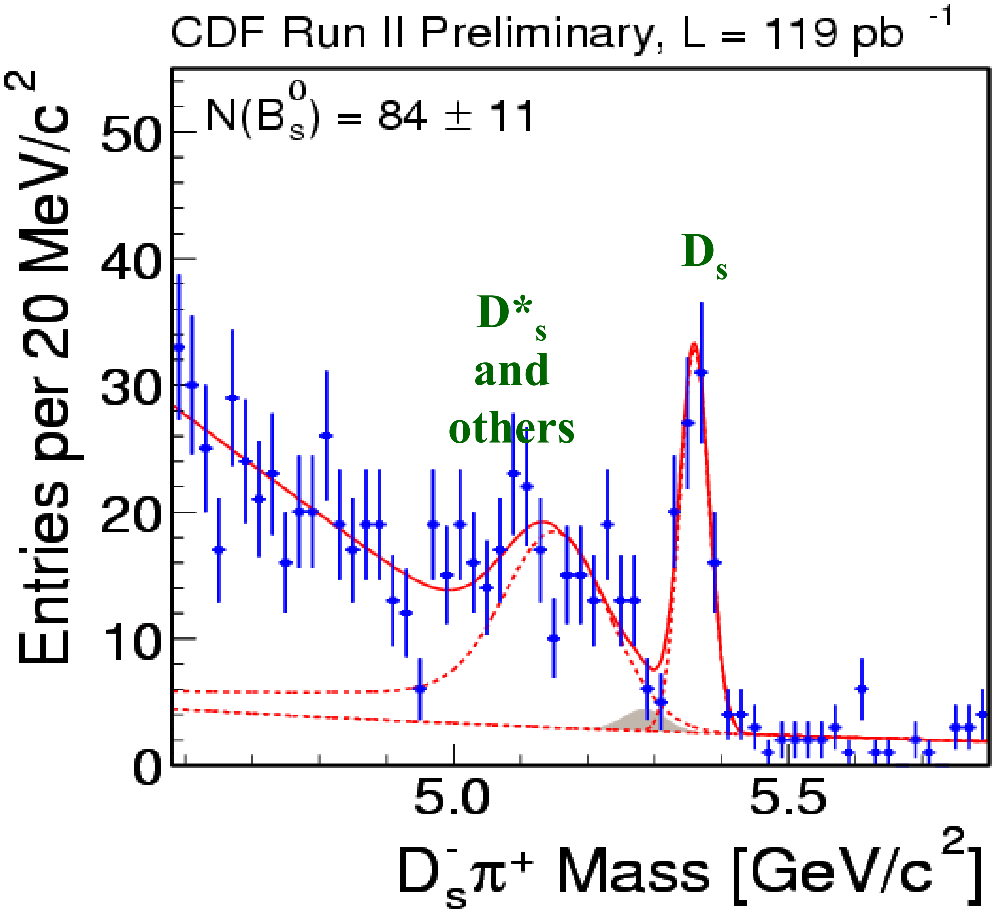




Semileptonic decays:

- Very good statistics but poorer time resolution
- If $\Delta m_s \cong 15$ ps^{-1} expect a 1-2 σ measurement with 500 pb^{-1}

Towards B_s mixing



Fully reconstructed hadronic decays:

- **Poorer statistics**
- **Excellent time resolution**
- **need a few fb^{-1} of data to reach**

$\Delta ms \simeq 18$ ps^{-1}

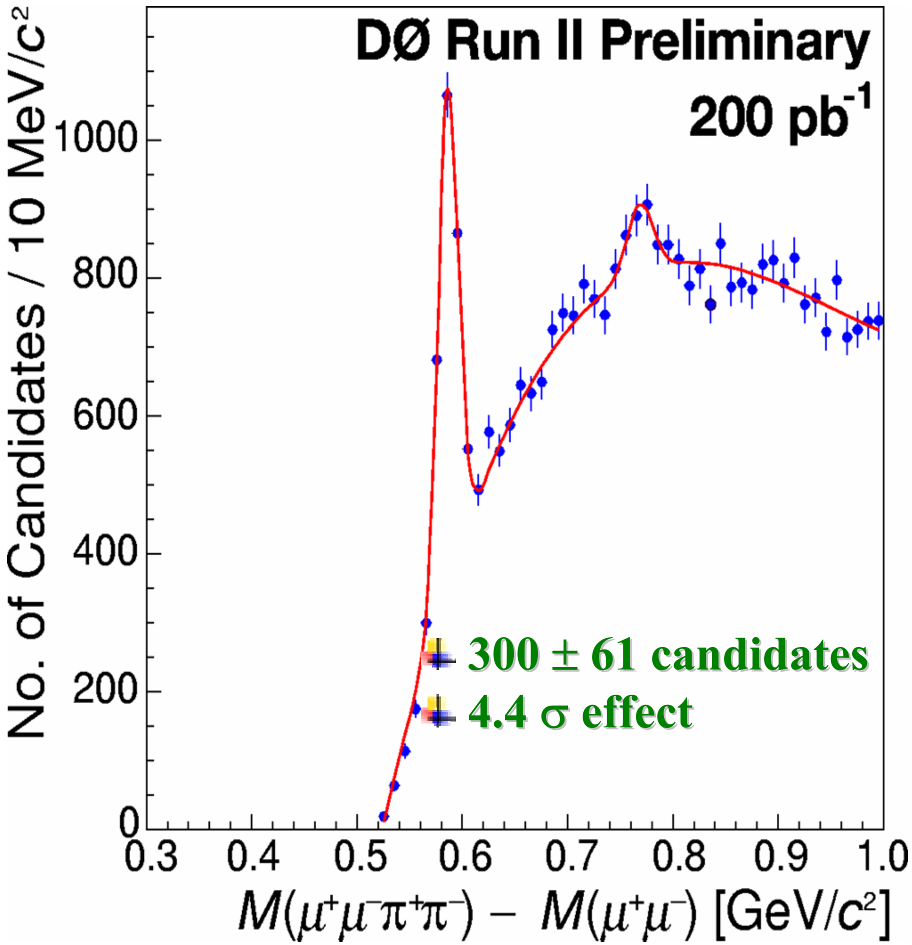
- **CDF "golden channel": $B_s \rightarrow D_s\,\pi$ maximum proper time resolution to resolve fast oscillations.**
- **$\sigma_{P_T(B)}/P_T(B) \approx 0.5\%$**
- **Reconstructed the signal with yield / lumi = 0.7/pb^{-1} and S/B ~ 2**

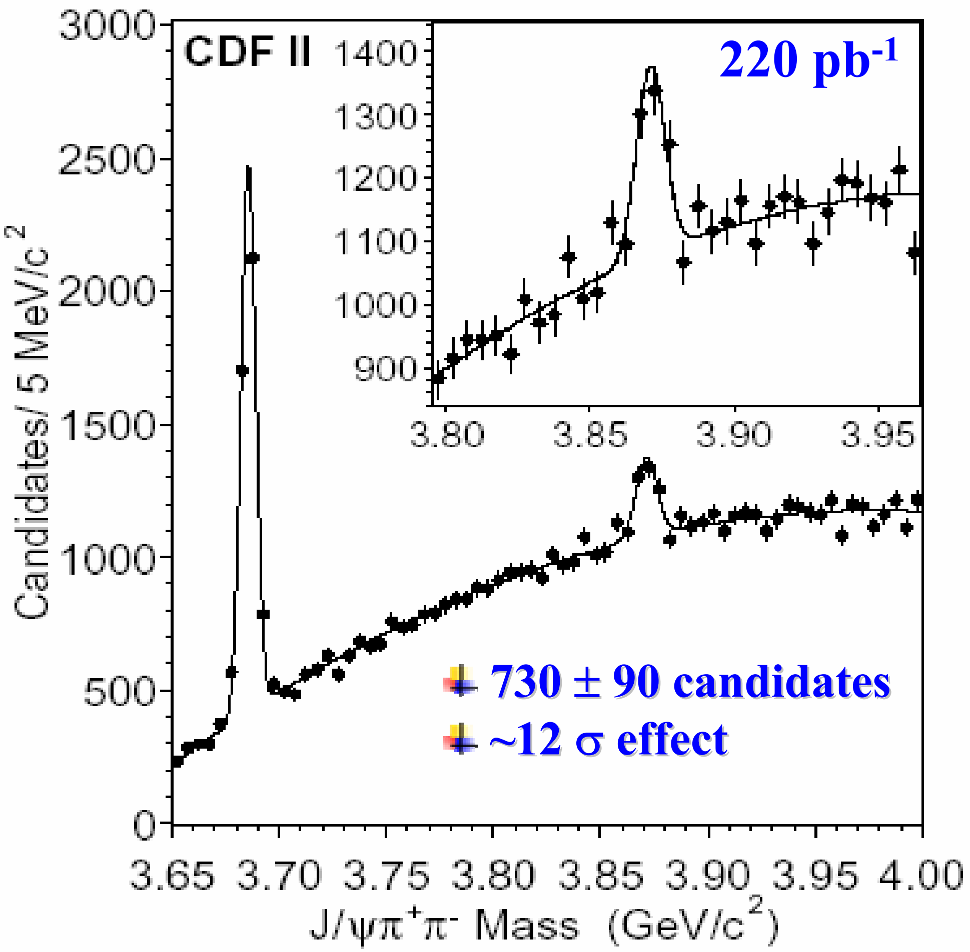
BR($Bs \rightarrow Ds\pi$) measured :

$\sigma_t = 67$ fs

$$\frac{f_s \cdot BR(B^0_s \rightarrow D^-_s \pi^+)}{f_d \cdot BR(B^0_d \rightarrow D^- \pi^+)} = 0.35 \pm 0.05(stat) \pm 0.04(syst) \pm 0.09(BR)$$

Both CDF & DØ have confirmed BELLE's discovery of the X(3872)





$\Delta M = 774.9 \pm 3.1(\text{stat}) \pm 3.0\ (\text{sys})\ \text{MeV}/c^2$

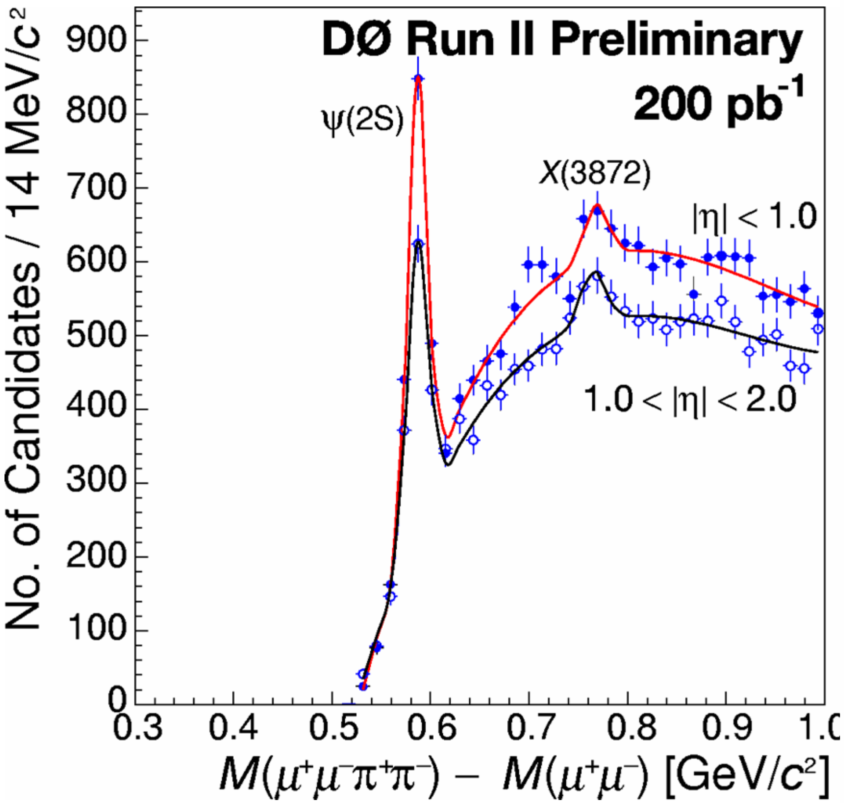
$\Delta M + M(J/\psi) = 3871.8 \pm 4.3\ \text{MeV}/c^2$

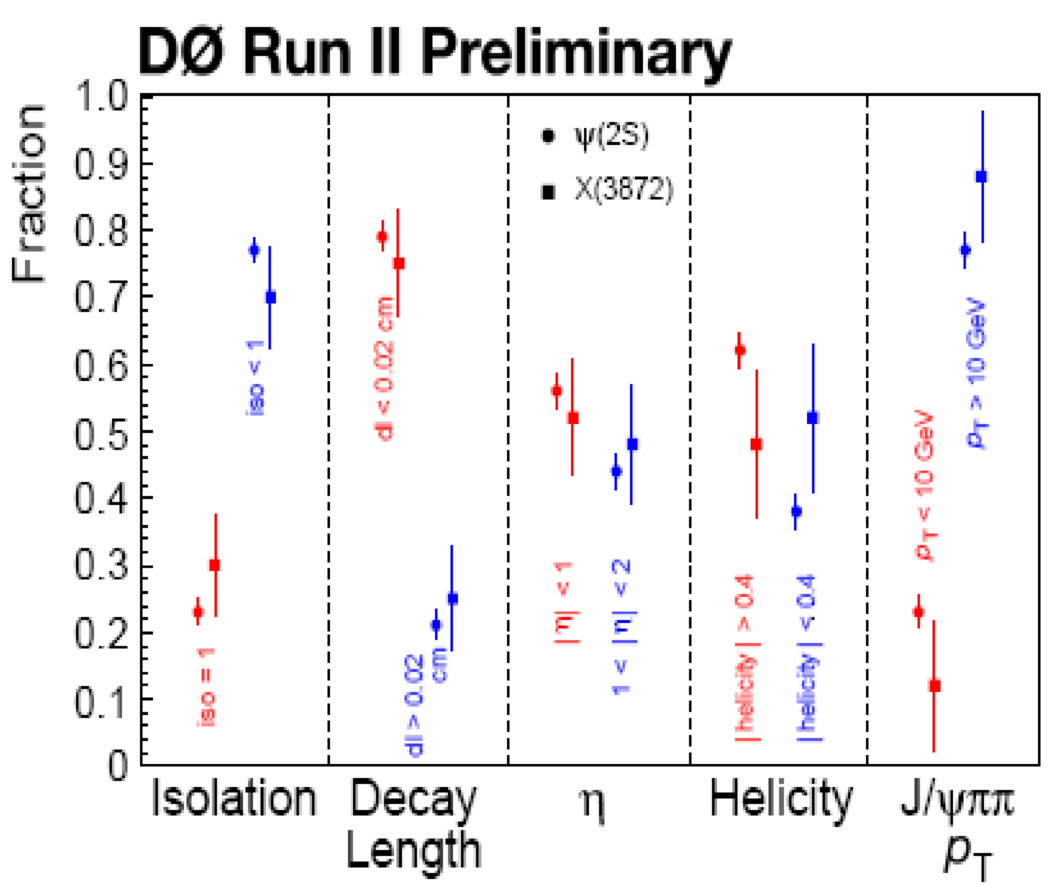
$M_X = 3871.3 \pm 0.7\ (\text{stat}) \pm 0.4\ (\text{sys})\ \text{MeV}/c^2$

Belle: $M_X = 3872.0 \pm 0.6\ (\text{stat}) \pm 0.5\ (\text{sys})\ \text{MeV}/c^2$

X(3872) – ψ(2S) comparison

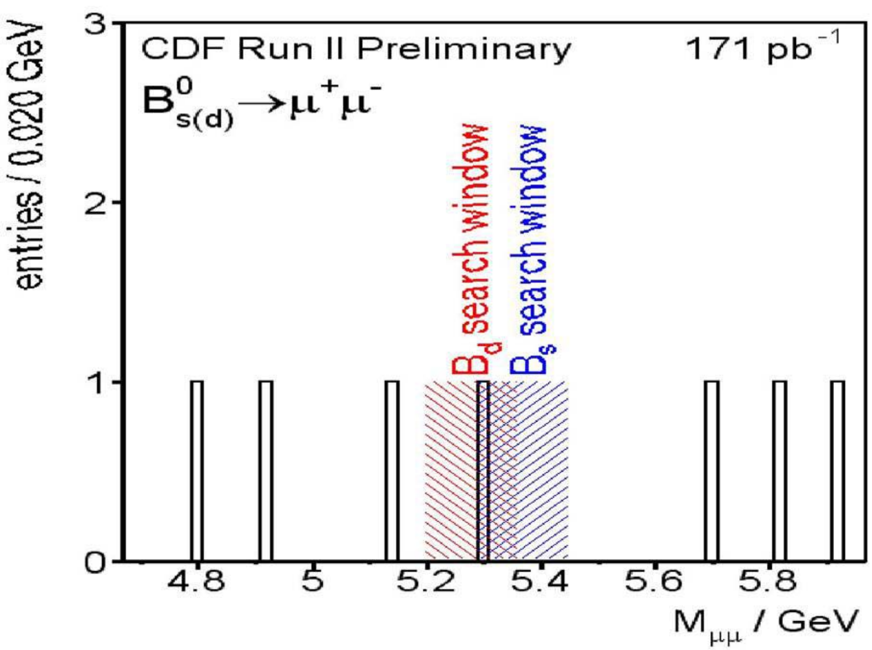
- **Is the *X* charmonium, or an exotic meson molecule?**
- **No significant differences between ψ(2S) and *X* have been observed yet**
- **From isolation and decay length comparisons, the production of X has the same mixture of prompt and long-lived fractions as the ψ(2S)**





Rare decays – $B_{d,s} \to \mu\mu$

- $BR(B_s \to \mu\mu) \sim 10^{-9}$ suppressed in SM (SUSY physics two orders of magnitude enhancement)
- Blind analysis optimized for 300-400 pb^{-1} ($\sim 1 \pm 0.3$ expected bkg)



Limits at 90% C.L.

$BR(B_s \to \mu^+ \mu^-) < 5.8\bullet10^{-7}$

$BR(B_d \to \mu^+ \mu^-) < 1.5\bullet10^{-7}$

B_s factor 3 better than best published limit (Run I)

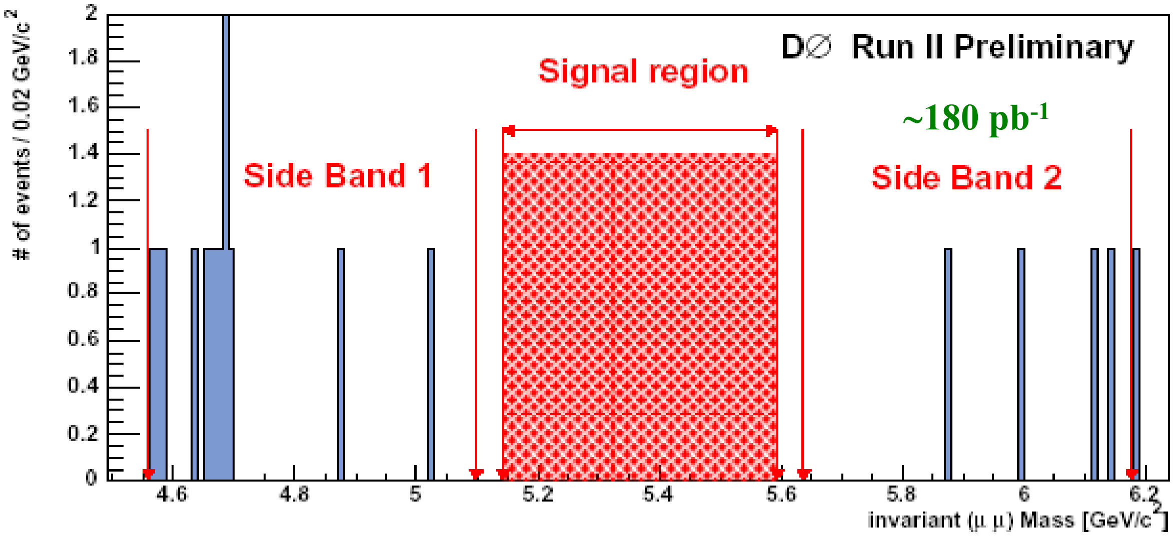
B_d slightly better than Belle's at LP03: 1.6 E-7@90%CL

Still room for improvement: ↑ Acceptance & ↓ bkgs

Rare decays - $B_s \to \mu\mu$

Optimised cuts using Random Grid Search [Prosper, CHEP'95; Punzi, CSPP'03] based on the mass sidebands. After optimisation:

- **expect 7.3 ± 1.8 background events in signal region**
- **signal efficiency: 30 %**



The analysis has not been *unblinded* yet (signal region still hidden).

It is still being optimized (without bias) and expected to improve …

Expected limit (Feldman/Cousins):

$$Br(B_s \to \mu^+ \mu^-) < 9.1 \cdot 10^{-7} \text{ @ 95 \% CL} \quad \text{(stat only)}$$
$$Br(B_s \to \mu^+ \mu^-) < 1.0 \cdot 10^{-6} \text{ @ 95 \% CL} \quad \text{(stat + syst)}$$

(expected signal has been normalised to $B^\pm \to J/\Psi\ K^\pm$)

CP Violation - Two body charmless decays $B \rightarrow h^+h^-$

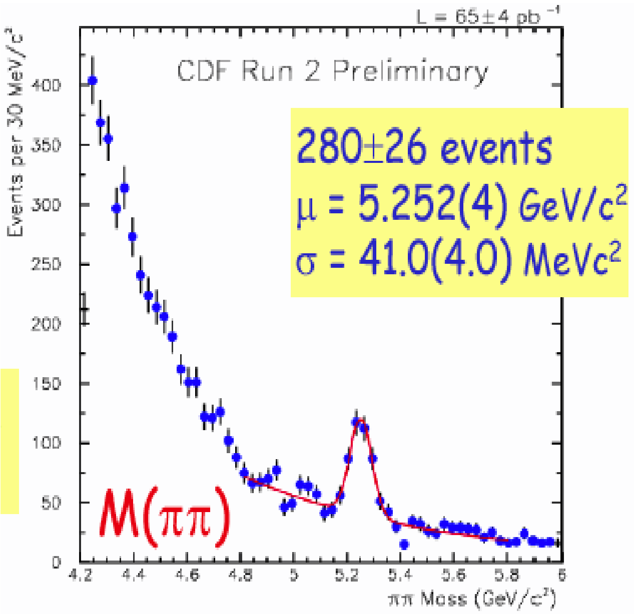
Time dependent asymmetry $B_d \rightarrow \pi\pi$ (α angle) and $B_s \rightarrow KK$ (γ angle)
Direct CP asymmetry of the self tagging modes $B_d \rightarrow \pi K$ and $B_s \rightarrow K\pi$

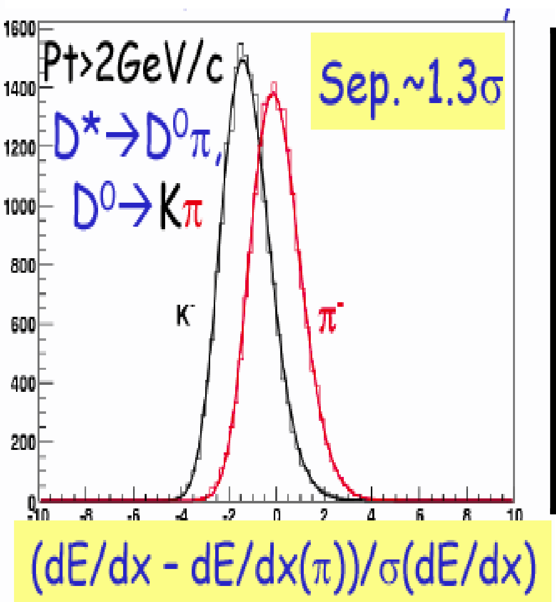
1. Extracting the signal

Displaced track trigger at L2 gives CDF accessibility to rare hadronic decays with high S/B.

2. Separation of the components

- **dE/dx ~ 1.3σ for K/p separation**
- **Statistical separation is still possible**
- **Unbinned log-likelihood fit defined including kinematical variables & dE/dx**

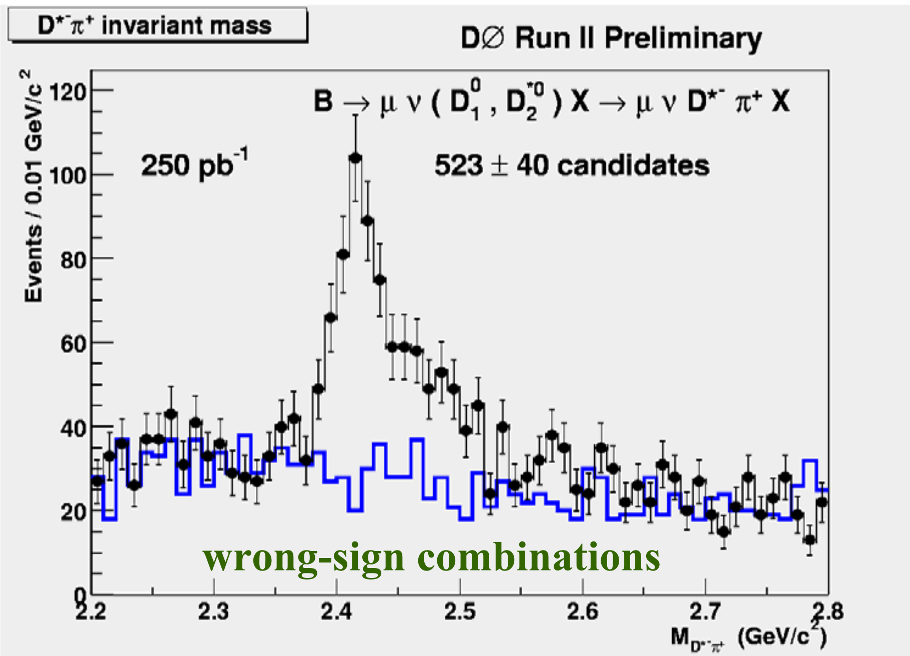


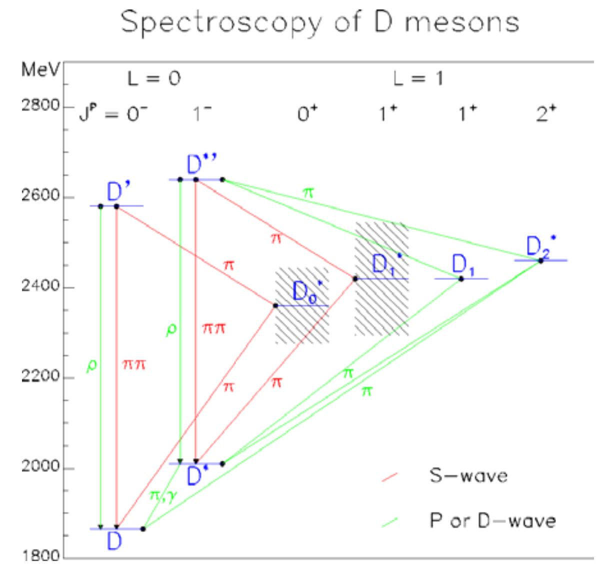


Mode	Yield (65 pb^{-1})
$B^0 \rightarrow K\pi$	148±17(stat.) ± 17(syst)
$B^0 \rightarrow \pi\ \pi$	39±14(stat.) ± 17(syst)
$B_s \rightarrow KK$	90±17(stat.) ± 17(syst)
$B_s \rightarrow K\pi$	3±11(stat.) ± 17(syst)

Observation of B → μ ν D** X

Start from our "$B \to \mu\, \nu\, D^{*-}$ + anything" sample, and "reconstruct another π^+".
Look at mass of $D^{*-}\, \pi^+$ system.





Excess in right-sign combinations can be interpreted as interfering D_1^0 and D_2^{*0}.

We study D_1^0, D_2^{*0} produced in semileptonic B decays. ⇒ Constrain D spectroscopy; also improve understanding of the sample of semileptonic B decays we use for lifetime, mixing, … measurements.

From topological analyses at LEP we know:

$Br(B \to D^{*+}\, \pi^-\, \mu\, \nu\, X) = 0.48 \pm 0.10$ %

DØ's preliminary result constrains the resonant contribution

$Br(B \to \{D_1^0, D_2^{*0}\}\, \mu\, \nu\, X) \cdot Br(\{D_1^0, D_2^{*0}\} \to D^{*+}\, \pi^-) = 0.280 \pm 0.021\ (stat) \pm 0.088\ (syst)\%$

Work in progress:
extract separate amplitude, phase for each state.

Summary

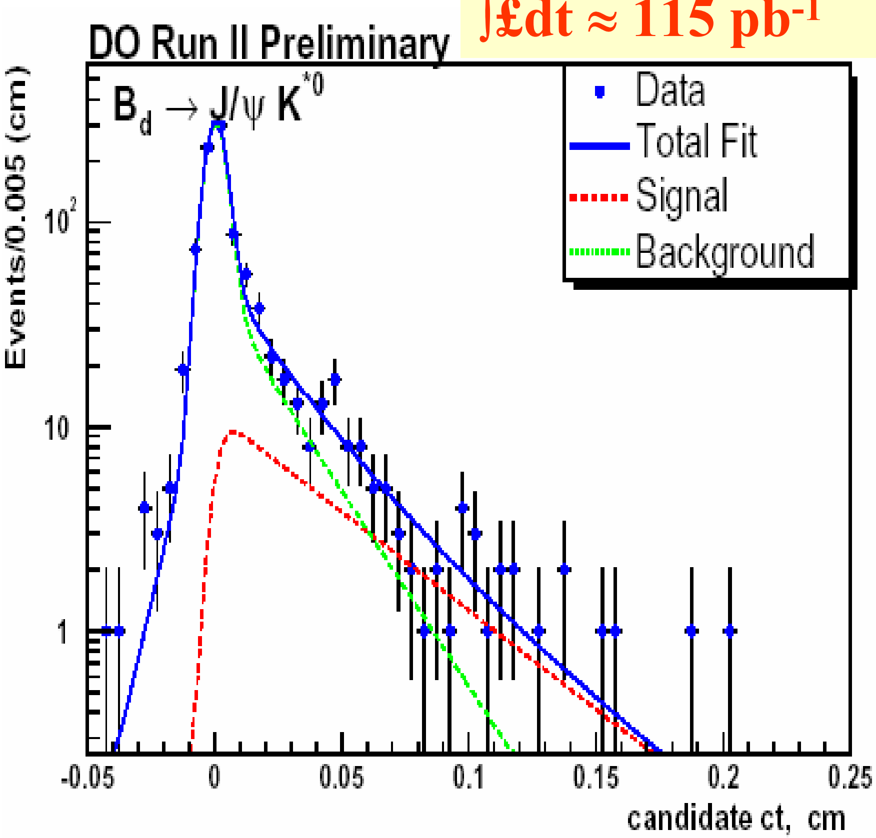
Excellent B physics prospects for Run II at Tevatron:

- **After 2003 fall shutdown, Tevatron has enjoyed substantial improvement and performance is steadily ramping.**
- **Tevatron offers a broad range of B physics programs.**
- **Both experiments have confirmed the discovery of X(3872).**
- **Competitive mass & lifetime measurements**
  - **eg. best in Λ_B & B_s mass measurements**
- **Both expts. are moving to attack B mixing in semi-leptonic & hadronic decays.**
- **Rare decays: look for physics beyond the standard model.**
  - **Set best limits in $BR(B_s \to \mu^+ \mu^-)$ & $BR(B_d \to \mu^+ \mu^-)$**

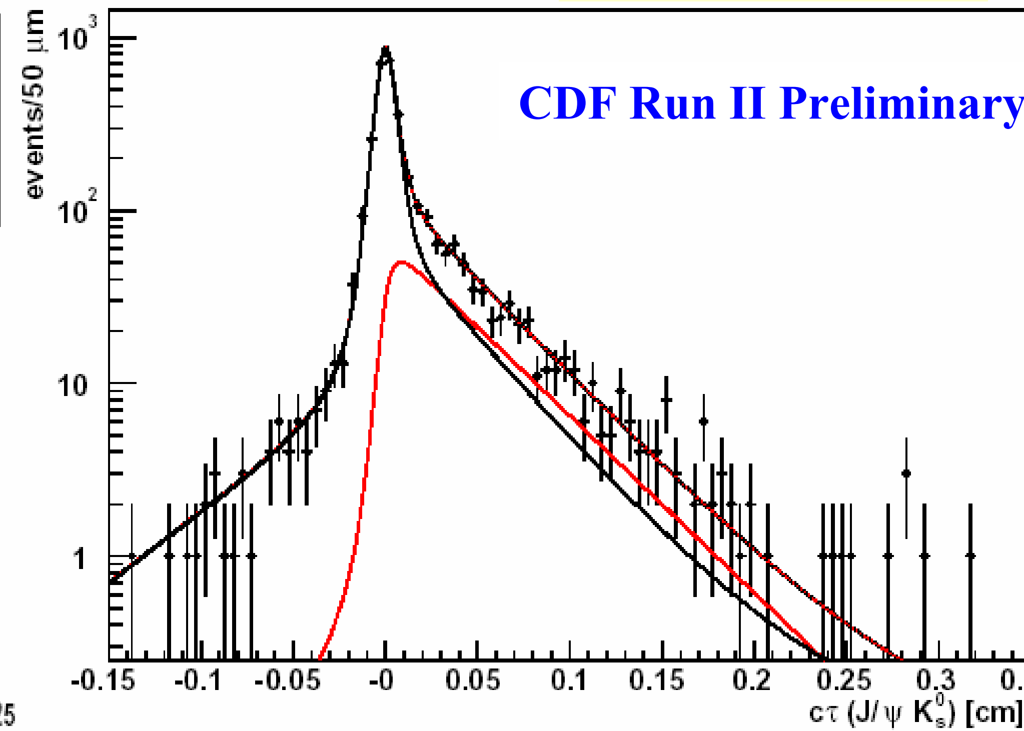
BACKUP

$B^{\pm}/B^0$ Lifetimes

$\int \mathcal{L}dt \approx 115\ pb^{-1}$



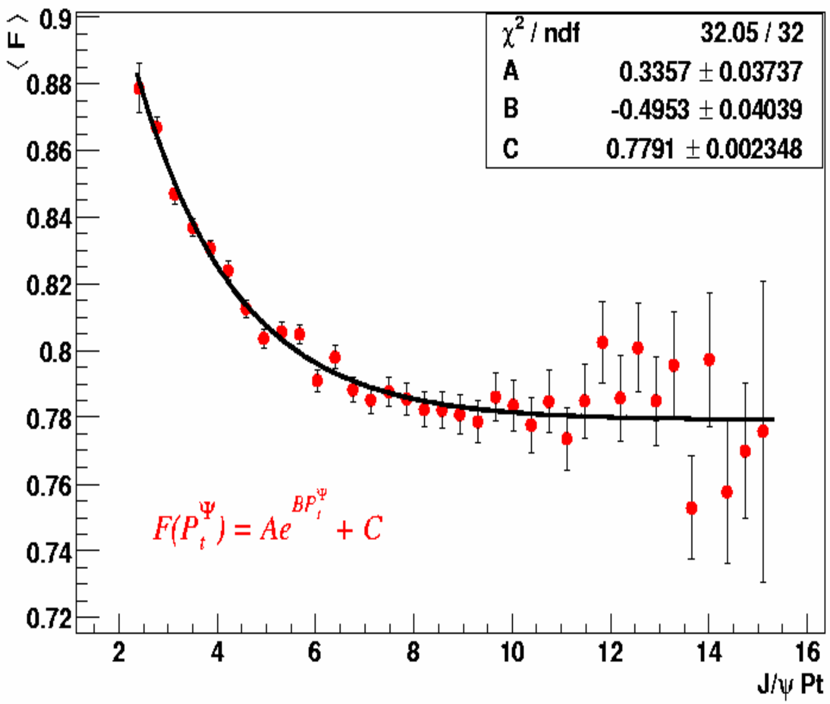
$\int \mathcal{L}dt \approx 138\ pb^{-1}$



B^+: $c\tau = 495 \pm 25(\text{stat})\ ^{+31}_{-37}(\text{sys})\ \mu m$
B^0: $c\tau = 453\ ^{+58}_{-51}(\text{stat}) \pm 60(\text{sys})\ \mu m$
$\tau_+/\tau_0 = 1.09\ ^{+0.15}_{-0.14}\ (\text{stat})\ ^{+0.16}_{-0.17}\ (\text{sys})$

B^+: $c\tau = 499 \pm 12(\text{stat}) \pm 6(\text{sys})\ \mu m$
B^0: $c\tau = 446 \pm 15(\text{stat}) \pm 8(\text{sys})\ \mu m$
$\tau_+/\tau_0 = 1.119 \pm 0.046(\text{stat}) \pm 0.014(\text{sys})$

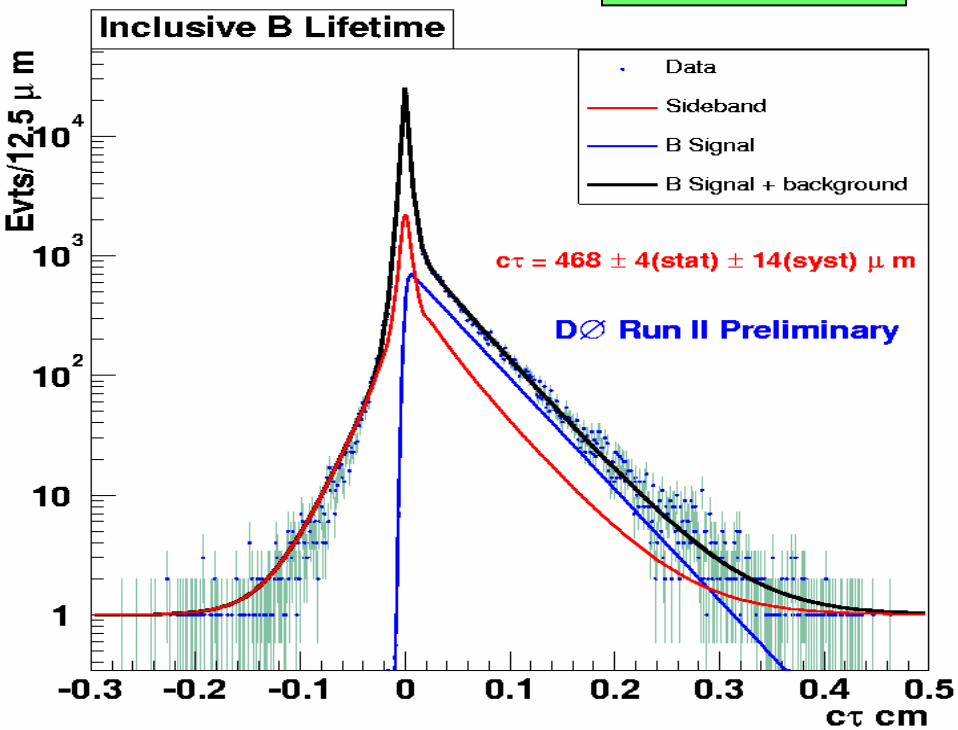
B Lifetime from Inclusive B → J/ψ+X



F: correction factor to use the pT(J/ ψ) to estimate the momentum of the B to find proper time. Obtained from Monte Carlo

$\int \pounds dt \approx 114\ pb^{-1}$

$$\lambda = \frac{L_{xy} M_{\Psi}}{P_{T\Psi} F(P_T)}$$



$\langle\tau\rangle = 1.564 \pm 0.014$ ps (PDG)

$\langle\tau\rangle = 1.562 \pm 0.013 \pm 0.045$ ps

Correction factor leads to the major systematic error

J/ψ from B's = 18%
… similar % seen at CDF